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16. Abstract Approximately 50,000 square miles of eastcentral Alaska were vegetation type mapped using LANDSAT MSS data. Modified clustering techniques were utilized and this method has significant advantages over supervised and unsupervised methods for processing LANDSAT data. The most important of these advantages are that the maximum number of readily separable information classes contained in the data are identified and extracted early in the analysis. Because this information is retained, multiple thematic applications are possible from the basic analytic result. The purpose of this investigation was preparation of moose habitat maps for Game Management Unit 20 but varied agencies, both public and private, intent to use investigational results in land selections, land-use planning, preparation of environmental impact statements, and habitat analyses for caribou and Dall sheep.

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USE OF LANDSAT IMAGERY FOR WILDLIFE HABITAT MAPPING IN NORTHEAST AND EASTCENTRAL ALASKA

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Final Report
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Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland 20771

Preface

The purpose of this investigation was to prepare vegetation type maps of Game Management Unit 20 for use by the Alaska Department of Fish and Game (ADF&G) in wildlife habitat evaluations. This area comprises about 50,000 square miles of eastcentral Alaska. Immediate application of results are for moose habitat assessments because moose populations in this area are the most urgent management concern. Investigational results provided most of the habitat information desired by the Department and, considering the size of the area, the only practical method of obtaining this information was analysis of LANDSAT data.

Investigational results will be used by a variety of agencies, although the analysis was funded by NASA and ADF&G. The United States Forest Service and the United States National Park Service will utilize results for evaluation and selection of D-2 lands authorized under the Alaska Native Land Claims Settlement Act. A consulting firm plans to utilize results in preparation of environmental impact statements.

Data processing methods utilized a modified clustering technique which has a number of distinct advantages over supervised and unsupervised techniques. These advantages include flexibility permitting multiple thematic use of basic analytic results, increased classification accuracy, and overall lower cost. The inherent informational content of LANDSAT data may be utilized in a variety of renewable resource application such as wildlife habitat analyses or timber inventories.

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LIST OF ABBREVIATIONS

ACWRU - Alaska Cooperative Wildlife Research Unit

ADF&G - Alaska Department of Fish and Game

BLM - Bureau of Land Management

NASA - National Aeronautics and Space Administration

USNPS - United States National Park Service

USFS - United States Forest Service

USFWS - United States Fish and Wildlife Service

dbh - Diameter at breast height

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USE OF LANDSAT IMAGERY FOR WILDLIFE HABITAT MAPPING IN NORTHEAST AND EASTCENTRAL ALASKA

INTRODUCTION

The purpose of this investigation was to produce vegetation type-maps for use in wildlife habitat assessments of Game Management Unit 20 (GMU 20). This area is delineated in Fig. 1 and comprises slightly more than 50,000 square miles.

The Alaska Department of Fish and Game is responsible for management of resident game species in Alaska. Within GMU 20, the most pressing management priority is moose (Alces alces) populations which have declined tremendously during the past six years. Recent management actions taken by the Department include establishment of areas closed to moose hunting, overall reduction of moose season length in GMU 20 from seventy days to ten days, a 100% increase in moose tage fees for non-resident hunters, and the highly controversial practice of predator control. The latter is the most drastic management action taken and emphasizes the gravity of the present situation.

No single factor can be clearly cited as cause for the moose population decline in GMU 20. Several interrelated factors have probably had a cumulative effect. First, the winters of 1970-71 and 1971-72 were exceptionally severe. Deep snow hindered moose feeding activity producing significant starvation losses and reduced productivity through fetus reabsorbtion or abortion. Also, predation losses were unusually high because wolves were able to hunt moose more efficiently in deep snow. Second, wolf numbers have increased to unusually high levels and placed considerable predator pressure on the moose population. Third, petroleum related development has initiated a human population boom in the past few years, so the number of human hunters in the field is probably greater than ever before. Finally, there are habitat considerations. Optimal winter range areas for moose are normally created by wildfire. The high brush stage of ecological succession lasting from about ten to thirty years after burning is especially favored winter range for moose. While many millions of acres were burned annually in years past, fire fighting efforts have become increasingly effective thereby reducing the number of acres burned each year. This is particularly true in GMU 20 because BLM fire control headquarters are located nearby in Fairbanks. Wildfires are normally reported sooner than in more remote areas and fire fighting crews are able to react quickly because of geographical proximity. Summarizing, the decline of moose populations in GMU 20 was probably caused by

cumulative factors including two unusually severe winters, high predator pressure, increased harvest by human hunters, and loss of winter habitat due to effective fire control.

In addition to the Department's management actions, there has been an increase in research designed to provide factual information about moose population changes and habitat requirements. The research includes studies of moose census techniques, calf survival, reproduction rates, patterns of seasonal use of habitat types, and assessment of existing habitat for moose in GMU 20. Therefore, this investigation is an integral part of a major goal directed research effort being carried out by ADF&G.

MAIN TEXT

I. Data used in the investigation

Seven LANDSAT scenes were selected and analyzed during the investigation (Table 1). Aerial reconnaissance data were obtained for 582 vegetation plots located throughout GMU 20 and more detailed data on site vegetation was obtained by ground visits to 255 sites (Table 2).

II. General methods of data analysis

LANDSAT scenes were selected for analysis based on desired geographic coverage, minimal cloud cover, and seasonal date with mid-summer being considered optimal. Two product formats were requested, namely 9.5 "false" color composite prints and 9-track computer compatible digital tape.

Areas to be analyzed on each scene were delineated using an overlay with the false color prints (Fig. 2). This permitted rapid approximation of desired data locations on corresponding digital tape data matrices.

After analytic areas were delineated, data were entered into the computer and a software routine was used to extract a 3% random data sample. The data sample was then processed with a cluster analysis software routine which usually generated between 15 and 30 cluster classes. The resulting cluster classes were used as a training set basis for maximum likelihood classification of remaining data. Following data classification with the maximum likelihood algorithm, full resolution, geometrically corrected, line printer maps were produced. These inexpensive preliminary products are 1:18,540 scale.

The line printer maps were taped together and mounted on large blank walls. Geographic orientation involved identification

of multiple features such as specific lakes and rivers on each printout. After orientation, spatial groupings of cluster classes were selected for aerial reconnaissance. In the selection process, no rigid criteria were applied, but we attempt to select spatial groupings large enough to locate with confidence and which were systematically distributed over the analytic area. For example, if a particular cluster class occurred in all subregions of the analytic area, we selected sites in all of those subregions. However, if class occurrence was confined to specific subregions such as flats or mountainous areas, we selected sites in only those subregions.

Generally, we attempted to select twenty sites for each cluster class when possible. Some classes were rare and/or spatially distributed such that they could not be adequately defined. We determined whether it would be practical to define the respective cluster classes after preliminary analysis of cluster statistics and examination of spatial distributions. Usually, there were one to three classes per scene which could not be adequately defined.

Sites selected for aerial reconnaissance were plotted on 1:63,360 maps. Portions of the line printer maps containing site information were cut out, labeled, and affixed to the appropriate 1:63,360 scale map. After completing all site selections, the boundaries of pertinent 1:63,360 maps were plotted on aeronautical charts (1:500,000 scale) along with indication of the total number of sites on each 1:63,360 map quad. This information was used for determining total number of flights required, the most efficient routing and fuel needs.

Aerial reconnaissance was conducted using single engine, high wing aircraft such as Cessna 150, Cessna 170, Cessna 180, Cessna 185, and Super Cub. In two position aircraft such as the Cessna 150 and Super Cub it was necessary for the pilot to aid in data gathering. Required data included accurate location of the site, description and recording of vegetation, and photography of the site. When it was necessary to use a two position aircraft, the pilot normally performed the navigational function of site location and described vegetation during low passes while the other person performed the photographic and secretarial functions. After several flights, we found it more efficient to use a larger aircraft and a three person team, namely, pilot, photographer/botanist, and a navigator/secretary.

Two types of aerial photography were used, namely 35mm color infrared and polaroid photography using a Polaroid Model 430 Land Camera. Although the polaroid prints were inferior

TABLE 1

LANDSAT data used in the investigation

Scene No.	Portion of GMU 20 covered
1029-20383	Southcentral
1407-20373	Northeast
1408-20430	Northwest
1408-20435	Southcentral
1422-20203	Southeast
1771-20513	Western
1771-20515	Southwestern

TABLE 2

Ground truth data obtained in the investigation

Scene No.	Aerial Reconnaissance Sites	Ground Sites visited
1029-20383	78	32
1407-20374	94	36
1408-20430	94	38
1408-20435	81	37
1422-20203	42	26
1771-20513	105	39
1771-20515	88	47
TOTAL	582	255

in quality, they had the distinct advantage of immediate availability. Site boundaries, LANDSAT scene number, cluster class number, and descriptive comments were recorded in flight directly on the polaroid print. These prints were stored in a small file box for each LANDSAT scene. The 35mm color infrared was obtained for later reference use and as a permanent photographic record.

Flight data was analysed shortly after it was obtained. Normally, flights were made in the morning and flight data analysed in the afternoon. These data were used for preliminary descriptions of cluster classes and selection of sites for ground visits.

Selection of sites for ground visit was based on two criteria. First, the number of ground sites selected for each cluster class depended upon class variability. If aerial reconnaissance data indicated relatively high class variability, six or more sites were selected for ground data collection. Conversely, if aerial reconnaissance data indicated relatively low class variability, only three sites were selected for ground data collection. For example, if twenty sites were examined from the air and all were mature stands of spruce forest, then only three ground sites would be selected. Alternately, six or eight sites would be selected for ground visit if twenty sites representing a particular cluster class were overflown and six were nontussock forming sedge meadow with low density tall shrubs, but no trees, eight were tussock forming sedge meadow with moderate density tall shrubs, but no trees, and the remaining six sites were tussock forming sedge meadow with low density tall shrubs and occasional poor growth form paper birch.

The second criteria for ground site selection was accessibility. Budgetary considerations prohibited use of a helicopter. Therefore, the remaining feasible means of transport for field personnel were highway vehicle, wheel plane, float plane, riverboat, canoe and travel on foot. Whenever possible, sites were selected less than three miles from an access point which could be reached by aircraft, boat, or highway vehicle.

The following data were obtained at each ground site if applicable:

Tree Story:

1. Per cent cover by species
2. Estimation of maximum, minimum, and mean dbh for each species
3. Presence or absence of saplings for each species
4. Estimation of mean height for each species

Tall Shrub Story:

1. Estimation of per cent cover by species
2. Estimation of browsing on each species: No browsing, less than 1/3 browsed, between 1/3 and 2/3 browsed, or more than 2/3 browsed.

Ground Cover:

1. Estimation of per cent cover by species for vascular plants with per cent cover of 5% or more
2. Estimation of per cent cover for fruticose, foliose, or crustose lichens with 5% or more cover
3. Estimation of per cent cover for bryophytes with 5% or more cover
4. Estimation of per cent cover for bare rock, bare ground, standing water, and litter if cover if 5% or more
5. Presence indication for all of the above if present but less than 5% cover.

General Comments

An overall description and ecological evaluation of each site was recorded in the field. This summary contained comments on seral succession, evidence of past fire, aspect, and use of the area by wildlife species.

The next step following field data collection was thematic analysis for moose habitat. ADF&G biologists determined seasonal patterns of use for different vegetation types from studies of radio collared moose. Using this information they compiled a listing of desired moose habitat types. These habitat classes were generally less specific than our analytic cluster classes. Therefore, a synthesis of cluster classes to fit the desired habitat classes was tabulated for each scene. This reduced the maximum number of classes for each scene to eleven habitat classes which were assigned individual colors (Table 3).

Color map products (1:250,000 scale) were then produced for all data analyzed. Additional color map products (1:63,360 scale) were produced for selected areas designated by ADF&G management biologists. These color products were produced by processing classified LANDSAT data through a computer interfaced with a film recorder. After production of a color internegative, the process was entirely photographic. All basic geometric corrections were effected during data processing rather than optically. Map scale for color products was produced optically using photographic processes.

TABLE 3

Moose habitat classification

Habitat Class	Color Assignment
Water	Blue
Bare ground or rock	White
Early pioneer communities	Gray
Late pioneer communities	Yellow
High brush	Red
Mature coniferous forest	Dark Green
Poor growth spruce/brushlands	Brown
Mixed coniferous/deciduous forest	Tan
Deciduous forest	Yellow-green
Wet tundra or sedge meadow	Magenta
Moist and dry tundra	Ochre
Other	Pink

III. Discussion of data analyses

Although the methods of data analysis delineated above were devised by the author late in 1974, several other investigators reached similar conclusions at about the same time. For example, the technique described as "modified clustering" by Fleming, Berkebile, and Hoffer (1975) is functionally identical to processing methods described above. Detailed discussion of the technique was presented in that paper which reports classification accuracies of 84.7%.

IV. Results

Brief descriptions of feature types corresponding to each cluster class by scene are presented in Tables 4 through 10. Table 11 summarized cluster class synthesis for the moose habitat theme.

Figure 3 is an example of the type of line printer map used by field crews for location of sites corresponding to each cluster class. Final products are color coded maps at 1:250,000 scale and 1:63,360 scale but reproduction costs prohibited inclusion of color products in this report.

Cluster means in bands 5 and 7 were plotted for each scene (Figs. 4 through 10). This type of graphic presentation is useful for obtaining preliminary indication of the nature of feature types corresponding to cluster classes. Each scene or portion thereof is unique as regards cluster statistics. However, feature types usually occur in the same relative positions on this type of graph. Figure 11 is a hypothetical example indicating relative position and gradients associated with cluster plots. Consequently, the approximate nature of feature types may be determined from these two dimensional graphs.

TABLE 4

Feature types corresponding to cluster classes on scene 1029-20383

Cluster No.	Feature Description
1	Birch-white spruce forest(birch dominant)
2	Black spruce heath
3	Light colored mud and rock
4	Early pioneer
5	Early successional fire recovery; birch-willow
6	Mature aspen forest
7	Black spruce bog
8	Mature birch forest
9	Upland white spruce/birch (spruce dominant)
10	Black spruce-birch heath
11	Mature white spruce forest
12	Upland brush (willow-birch-alder)
13	Moist tundra (spaghnum dominant)
14	Moist tundra (*Eriophorum tussock*)
15	*Populus balsamifera* forest
16	Dark colored mud and silt
17	Alpine tundra
18	Black spruce-tamarack muskeg
19	Deep clear water
20	Late pioneer community
21	Alluvial silt
22	Silty water
23	Shallow clear water
24	Gravel
25	Late pioneer community
26	Gravel
27	Bare ground or rock

TABLE 5

Feature types corresponding to cluster classes on scene 1407-20374

Cluster No.	Feature Description
1	Bluff community; poor growth form deciduous trees and juniper, <u>Artemesia</u>, grass, and bare rock on steep slopes
2	Black spurce heath
3	Spruce muskeg
4	Late successional spruce forest
5	Immature balsam poplar forest
6	Late pioneer community; immature balsam poplar and willow
7	Mature spruce forest
8	Shallow water
9	Wet mud and rock; river beaches
10	High brush; willow-alder
11	Early pioneer community; immature deciduous trees and brush with considerable bare rock; usually river island succession or bluff community
12	Black spruce bog
13	Mixed deciduous forest
14	Alluvial mud and gravel
15	Mature balsam poplar
16	Deep water

TABLE 6

Feature types corresponding to cluster classes on scene 1408-20430

Cluster No.	Feature Description
1	Late pioneer; willow-balsam poplar
2	Spruce bog or heath
3	Mixed forest (spruce dominant)
4	Alluvial silt and gravel
5	High Brush; willow
6	Mature white spruce
7	Dense treelike willow occasionally mixed with balsam poplar
8	Clear water
9	Deep silty water
10	Wet alluvial silt
11	Early pioneer community; river island succession
12	Tall treelike willow and/or immature balsam poplar
13	Shallow silty water
14	Early pioneer community; river island succession
15	Wet mud

TABLE 7

Feature types corresponding to cluster classes on scene 1408-20435

Cluster No.	Feature Description
1	Black spruce heath
2	Mixed spruce forest
3	Birch-spruce forest (birch dominant)
4	Black spruce-birch heath
5	Deep water
6	Mature birch forest
7	Undefined; probably clouds
8	Undefined; probably snow and/or cloud
9	Silty water
10	Aspen forest
11	Undefined; probably snow and/or cloud
12	Silty water
13	Undefined; probably snow and/or cloud
14	Unvegetated mine tailings, gravel
15	High brush; willow
16	Very sparsely vegetated sand and/or gravel
17	Light colored rock
18	High brush community; almost completely vegetated mine tailings, mid-succession on river islands, etc.; principally high brush willow
19	Mud and silt
20	Late pioneer community; moderately vegetated mine tailings, river islands, or disturbed areas; vegetative cover consists principally of willow and deciduous tree seedlings
21	Closed canopy spruce-birch forest
22	Mixed decidous forest
23	Mid-successional pioneer community
24	Mixed coniferous-deciduous forest
25	Shallow clear water
26	Mid-successional birch forest

TABLE 8

Feature types corresponding to
cluster classes on scene 1422-20203

Cluster No.	Feature Description
1	Light colored rock
2	Spruce heath
3	Spruce heath
4	Mixed forest (spruce dominant)
5	Mid-successional spruce forest
6	Alpine tundra; some bare rock
7	Mud
8	Bluff community; early pioneer
9	Deep water
10	Mixed forest (deciduous dominant)
11	Mature spruce forest
12	Bluff community; late pioneer
13	Bluff community; early pioneer
14	Bluff community; late pioneer
15	Alpine tundra; completely vegetated
16	Bluff community; early pioneer
17	Silty water
18	Alpine tundra; significant bare rock
19	Spruce heath
20	Silty water
21	Spruce heath
22	Mid-successional spruce forest
23	Bare rock
24	Gravel
25	Bluff community; early pioneer

TABLE 9

Feature types corresponding to cluster classes on scene 1771-20513

Cluster No.	Feature Description
1	Light gray rock
2	Spruce bog or heath
3	High brush
4	Mixed coniferous deciduous forest
5	Silty water
6	Mixed coniferous deciduous forest
7	Black spruce forest
8	Brushy alpine tundra
9	Deep water
10	Birch-aspen forest
11	Shallow water
12	Early pioneer community; mostly rock
13	Late pioneer community; high brush and rock
14	Mature spruce forest
15	Moist alpine tundra
16	Birch forest
17	Gravel
18	Late pioneer community; grasses & brush
19	Gravel
20	Wet tundra; wet sedge meadows
21	Alpine tundra; significant bare rock
22	Bare rock
23	Early pioneer; mostly rock
24	Deciduous forest on steep slopes
25	Early pioneer; mostly rock

TABLE 10

Feature classes corresponding to cluster classes on scene 1771-20515

Cluster No.	Feature Description
1	Black spruce forest
2	Black spruce heath
3	Bare rock
4	Aspen-birch forest
5	Deep clear water
6	Mixed deciduous-coniferous forest
7	Mature spruce forest
8	Spruce bog or heath
9	Deep silty water
10	Shallow silty water
11	Early pioneer community; mostly rock
12	Muskeg
13	Cloud
14	Shallow clear water
15	High brush
16	Black spruce-birch heath
17	Mud
18	Late pioneer community; high brush and grasses
19	Alluvial silt and gravel
20	Bare ground and rock
21	Late pioneer community; high brush and sedges
22	Snow

TABLE 11

CLUSTER CLASS SYNTHESES FOR MOOSE HABITAT THEME

Habitat Type	Scene No. & Cluster Groupings 1029-20383	1407-20374	1408-20430	1408-20435	1422-20203	1771-20513	1771-20515	Color Assignment
Water	19,22 23	8 16	8,9 13	5,9 12,25	9,17 20	5,9 11	5,9 10,14	Blue
Bare ground or rock	3,4,16 21,24 26,27	9 14	4,10 15	14,16 19	1,7 24	1,17 19,22	3,17 19,20	White
Early Pioneer Community	4 17	1 11	11 14	17	8,13 16,25	12,21 23,25	1	Gray
Late Pioneer Community	20 25	3 6	1	20 23	23	13 18	18 21	Yellow
High Brush	12	10	5	18 15	14 12	3	15	Red
Coniferous Forest	9,11	4 7	6	2 21	5,11 22	7 14	9	Dk. Green
Spruce bog, heath, or muskeg	2,7 10,18	2 12	2	1 4	2,3 19,21	2	17	Brown
Mixed coniferous-deciduous forest	1		3	3 24	4 10	4 6	18	Tan
Deciduous Forest	5,6 8,15	5,13 15	7 12	6,10 22,26		10,16 24	8	Yellow-Green
Wet Tundra						20		Magenta
Alpine tundra	13,14			6,15,18		8,15		Ochre
Other	20,25			7,8, 11,13			13,22	Pink

V. Practical applications of results of the investigation

Short term practical applications of results include wildlife habitat assessments within GMU 20, preparation of environmental impact statements for military land withdrawals, and land classification for use in land selections authorized under the Alaska Native Land Claims Settlement Act.

Long term application of results is anticipated in statewide resource inventory, land-use management, and ecosystem studies. Until recently, detailed vegetation type mapping of an area as large as Alaska was not feasible. The use of LANDSAT data, however, does permit cost feasible vegetation type mapping of Alaska within a reasonable time period and using a single method of classification.

In the past, many individuals carried out vegetation studies of relatively small areas scattered throughout the state (e.g. Calhane, 1959; Hanson, 1951; Hettinger and Janz, 1974; Young, 1974). The authors utilized a variety of technical methods for preparing these maps and often devised their own system of vegetative community classification. The task of unifying this disparate information to obtain a comprehensive overview of existing data is extremely difficult. Nevertheless, this task is being attempted by a committee of botanists, ecologists, foresters, and soil scientists at the University of Alaska. They are reviewing all past community descriptions for the subarctic and arctic. The goal of this effort is formulation of a single classification system for the vegetational communities of these regions.

Results of this investigation appear to be compatible with the classification system currently proposed by this committee. Further, the author has utilized the same methods for vegetation type mapping other portions of Alaska. These other projects are not directly related to this investigation and have been funded by various organizations including the U.S. Fish and Wildlife Service, the U.S. National Park Service, the Sierra Club Foundation, and Calista Corporation. Two of these projects are still in progress with anticipated completion dates of mid-1977. When these projects are completed vegetation type mapping based on a single method of classification will exist for 175,000 square miles or roughly 1/3 of Alaska's landmass. LANDSAT based vegetation type maps may exist for the entire State by 1980.

If the rate at which LANDSAT data are being applied to vegetation type mapping continues indications are the use of LANDSAT data for vegetation type mapping of large areas in Alaska will continue. For example, BLM, the USFS, and the USNPS have planned projects involving application of LANDSAT data for vegetation type mapping.

Consequently, the most significant long term application of results is likely as a partial contribution to a statewide vegetation type mapping based on LANDSAT data classification. This will permit the first synoptic inventory of Alaskan renewable resources.

VI. Use of results and their applications by operational agencies

The immediate application of results by ADF&G is for habitat inventory of GMU 20 in connection with their research and game management program for moose. Future applications of results by ADF&G will probably include habitat inventories for Dall sheep and caribou in GMU 20.

Because these results are in the public domain, several other organizations anticipate their use. The U.S. Forest Service has requested use of results in connection with proposed D-2 land selections for the Porcupine National Forest. This will require additional data classification because our analysis did not extend beyond the boundaires of GMU 20. LANDSAT scene 1407-20374 does cover the D-2 lands being considered, however, and our analysis has already generated cluster statistics and field definition. Therefore, the task is reduced to a matter of classifying additional portions of the scene and producing the desired color map products using a timber inventory theme rather than the moose habitat theme. We are currently negotiating a contract with Mr. Sig Olson of the U.S. Forest Service for this work.

The U.S. National Park Service has requested these results for use in selection of D-2 lands proposed as additions to Mount McKinley National Park. Mr. Ralph Root, Mr. Steven Buskirk, and Ms. Terra Prodan of the USNPS have followed the progress of our investigation and intend to use these results as soon as they are available. There were, however, certain areas within the Park and to the north which were not covered by the analysis. Because USNPS is concerned with habitat assessments of these lands, Dr. Frederick Dean has undertaken analysis of portions of three LANDSAT scenes which provide coverage of areas. Dr. Dean is Leader of the Cooperative Park Research Unit (USNPS) and is headquartered in offices adjoining ACWRU. We have provided assistance with his analysis on several occasions.

A consulting firm has requested our results as soon as available for use in preparing an environmental impact statement.

To date, the above are the only organizations which have requested immediate use of the results of this investigation. However, a variety of State, Federal, and private agencies are presently involved with Alaskan land selections,

preparation of environmental impact statements and renewable resource assessments. These organizations will probably desire use of these results in the near future.

CONCLUSIONS

There are five fundamental advantages of the modified clustering technique used in this investigation.

First, the principal informational content of the LANDSAT data is extracted and retained. Informational class synthesis does not occur until generation of a thematic product. Therefore, results of the cluster classification are retained on the classified digital tape.

Second, because of this, multiple thematic applications are possible without reclassification of raw data. For example, thematic class syntheses may address moose habitat, caribou range, waterfowl habitat, timber value, and/or a variety of other themes. This flexibility presents a definite advantage over supervised classification methods.

Third, the modified clustering technique may be implemented with software on general purpose computer systems . Specialized interactive systems with color television display of data are not required.

Fourth, ground truth is not initially required with modified clustering and, after data classification, ground truth activity is specifically goal directed to definition of feature types corresponding to each cluster class.

Fifth, thematic classification accuracies reported for modified clustering are superior to classification results obtained with either supervised or unsupervised techniques (Fleming, Berkebile, and Hoffer,1975)

Therefore, we conclude the modified clustering technique is currently the most effective method for achieving goal directed applications of LANDSAT data.

In connection with this technique, two dimensional graphic plots of cluster results are useful for determining the approximate nature of feature types corresponding to cluster classes.

The use of LANDSAT data permits mapping of large areas in a short time period and is cost-feasible for most operational agencies. The utility of analytic result varies depending upon the specific thematic application. However, LANDSAT based analyses usually provide most information desired by thematic users involved with renewable resource assessments. For example, in this investigation, small stands of riparian

willow occurring along minor drainages were not detected and classified because of the inherent limitations of LANDSAT data resolution. Since these riparian willow stands are important winter browse for moose, ADF&G must obtain this information by conventional means to complete their habitat evaluation. Nevertheless, almost all of the desired habitat information was obtained through the LANDSAT analysis and, from a practical cost standpoint, could not have otherwise been obtained.

Similarly, LANDSAT data applications to caribou range have limitations which require supplemental information because parameters other than vegetation enter into caribou habitat evaluation. For example, a difference of 15 or 20 cm in annual snowfall may determine whether a particular area with sufficient forage is adequate winter range or marginal to unsatisfactory winter range for caribou. Additionally, factors such as windpacking of snowcover and frequent formation of ice crusts must also be considered. Even though an abundance of high quality forage may exist in a particular area, climatological factors may totally preclude the use of the area by wintering caribou. Therefore, LANDSAT based analyses of vegetation types provide potential range assessments which must be supplemented and modified using climatological data.

Summarizing, LANDSAT data provide a timely cost effective vehicle for vegetation type mapping of large areas. This information contributes significantly to renewable resource assessments such as wildlife habitat and timber resource evaluations. The most effective current method of applying LANDSAT data is the modified clustering technique.

NEW TECHNOLOGY

Overall data processing methods as presented in Section II, General methods of data analysis may be considered new technology. This technique has been termed "modified clustering" by others (Fleming, Berkebile, and Hoffer, 1975).

APPENDIX I: Definition of feature classifications

Water - self explanatory

Bare ground or rock - This classification comprises all areas which are devoid or almost devoid of vegetation. Within GMU 20, the areas so classified are principally mountain barrens or unvegetated river islands and beaches. However, the classification includes such features as urban areas, roads, airstrips, unvegetated mine tailings, and other unvegetated areas.

Early pioneer community - This classification refers to areas which are generally less than 50% vegetated with bare rock or soil comprising 50% or more of total ground cover. Within GMU 20, the areas so classified are principally an ecotone between alpine tundra and mountain barrens or early stages or river island succession. However, the classification may include a variety of other feature types such as agricultural fields in early growth, abandoned airstrips or mine sites which are beginning to revegetate, and even urban or residential areas wich contain a mixture of vegetation and non-vegetation as ground cover.

Late pioneer community - This classification refers to areas which are incompletely vegetated but where ground cover is dominated by vegetation. Within GMU 20, the areas so classified are principally high brush with or without the presence of immature deciduous trees. These areas are usurlly river islands but may be abandoned mine sites, air strips, or agricultural fields. Bare rock, gravel, or soil is usually a significant but not dominant feature of total cover.

High brush - This classification refers to areas dominated by high brush, especially willow. These areas include large patches of riparian willow, brushy meadows and hillsides in alpine areas, and areas of high brush resulting from past fires or secondary succession on human disturbance areas.

Coniferous forest - This class consists of mature or nearly mature, relativel dense, good growth form spruce. These stands are normally white spruce (*Picea glauca*) but may include black spruce (*Picea mariana*) or a mixture of both species.

Spruce bog, heath, or muskeg - This class consists of poor growth form spruce at relatively low density. At lower elevations, this classification is normally black spruce bogs or heath meadows but, at higher elevations, treeline white spruce classifies to this type.

Mixed coniferous - deciduous forest - This class consists of a mixture of coniferous and deciduous trees with either dominating. Such mixtures are common in fire recovery areas 30 to 90 years after burning. Deciduous trees such as paper birch (*Betula papyrifera*) and/or quaking aspen (*Populus tremuloides*) dominate the post-brush stages of recovery but are eventually replaced by mature spruce forest. During this transition, mixed forests occur.

Deciduous forest - This class encompasses mature stands of balsam poplar (*Populus balsamifera*), mixtures of birch, aspen, and/or balsam poplar occurring as successional stages, and mature, reproducing stands of paper birch. To some extent, dense stands of tall treelike willow, particularly *Salix alaxensis* and *Salix arbusculoides*, may be so classified.

Wet tundra - Wet sedge meadows dominated by water and/or non-tussock forming sedges

Alpine tundra - In this context, this class includes both moist tundra and dry alpine tundra where vegetational cover is nearly complete. Therefore, the class may vary from moist areas dominated by *Spaghnum* moss, sedges, and low brush to drier areas dominated by *Dryas*, *Empetrum*, and *Vaccinium*.

Other - This class is used for cluster groupings which are not compatible with the above groupings. Clusters in this group are usually snow and/or clouds.

GLOSSARY

Alaska Native Claims Settlement Act - An act of the U.S. Congress (1971) which provided both land and monetary settlement of the land claims of the Alaskan Indians, Eskimos and Aleuts. The Act provides for Native ownership of approximately 40 million acres of land as well as compensation of nearly $1 billion over a 20 year period. The Act also provides for approximately 80 million acres of Federal land (under section D-2) to be set aside for possible additions to the National Park, Wildlife Refuge, National Forest and Wild and Scenic Rivers systems.

Algorithm - A set of computer instructions for data classification decisions, i.e., programmed decision criteria (See maximum likelihood).

Classification accuracy - As used in this report, this term refers to average classification accuracies as determined by ground truth.

Grouth truth - Within the context of this report, the term "ground truth" broadly refers to data obtained relatively close to the earth surface. Aerial photography and observation are included in this broad definition as well as actual on the ground data collection.

Interactive system - This refers to a computer system with data display capability where the operator may interact directly in the process of data analysis. Examples of such systems include the Image 100 marketed by General Electric and M-ADS marketed by Bendix Corporation.

LANDSAT data - Through the context of this report, the term "LANDSAT data" refers to multispectral scanner data sometimes called MSS data. These data are reflectance measurements in four specific regions of the electromagnetic spectrum. Detailed information on the nature and types of data obtained by LANDSAT series satellites may be found in the LANDSAT Data Users Handbook, Document No. 76SDS4258 published by NASA at Goddard Space Flight Center, Greenbelt, Maryland.

Maximum likelihood - A decision algorithm based on Gaussian quadratic discriminant functions. This algorithm assumes normal distribution of data and calculates probability that a multivariate data set belongs to a particular distribution (see algorithm).

Modified clustering - A technique which may be used for analysis of LANDSAT data. This technique employs cluster analysis to initially classify data to a number of informational classes. Resulting cluster classes are then recombined according to informational needs desired for a particular theme such as timber value (See supervised and unsupervised).

Primary succession - The process of evolution from abiotic mineral strata to a climax ecosystem consisting of biotic and abiotic components. This is a long term process involving the breakdown of mineral rock, formation of soils, and progressive evolution to a relatively stable climax ecosystem.

Secondary succession - Seral succession resulting from a disturbance of primary succession. Examples include fire and human disturbance where the existing ecosystem is disburbed. Recovery from such disturbance is secondary succession. This process is relatively short term compared to primary succession because soils are already formed and natural seed sources are available.

Succession - An ecological term referring to seral succession. This may be primary or secondary (see primary succession and secondary succession)

Supervised classification - A technique which may be used for analysis of LANDSAT data. With this technique, direct data classification to thematic informational classes is attempted using interactive methods (See interactive system). This is accomplished using an interactive computer system where the operator views data displays, directs selection of data for training, views classification results, and continues training until satisified with results (See modified clustering and unsupervised).

Thematic analysis - Data analysis addressing the informational needs of a specific theme such as moose habitat or timber value.

Unspervised classification; cluster analysis of data - This technique may be used for analysis of LANDSAT data. It is essentially the first phase of modified clustering but does not proceed to recombination of classes to meet the informational needs of a particular theme.(See modified clustering and supervised classification).

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Hanson, H. C. 1951. Characteristics of some grassland, marsh, and other plant communities in western Alaska. Ecological monographs 21:317-378.

Hettinger, L.R. and A. J. Janz. 1974. Vegetation and soils of northeastern Alaska. Arctic Gas Biol. Rept. Series, Vol. 21, 206p.

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INDEX

Fig. 1. Game Management Unit 20

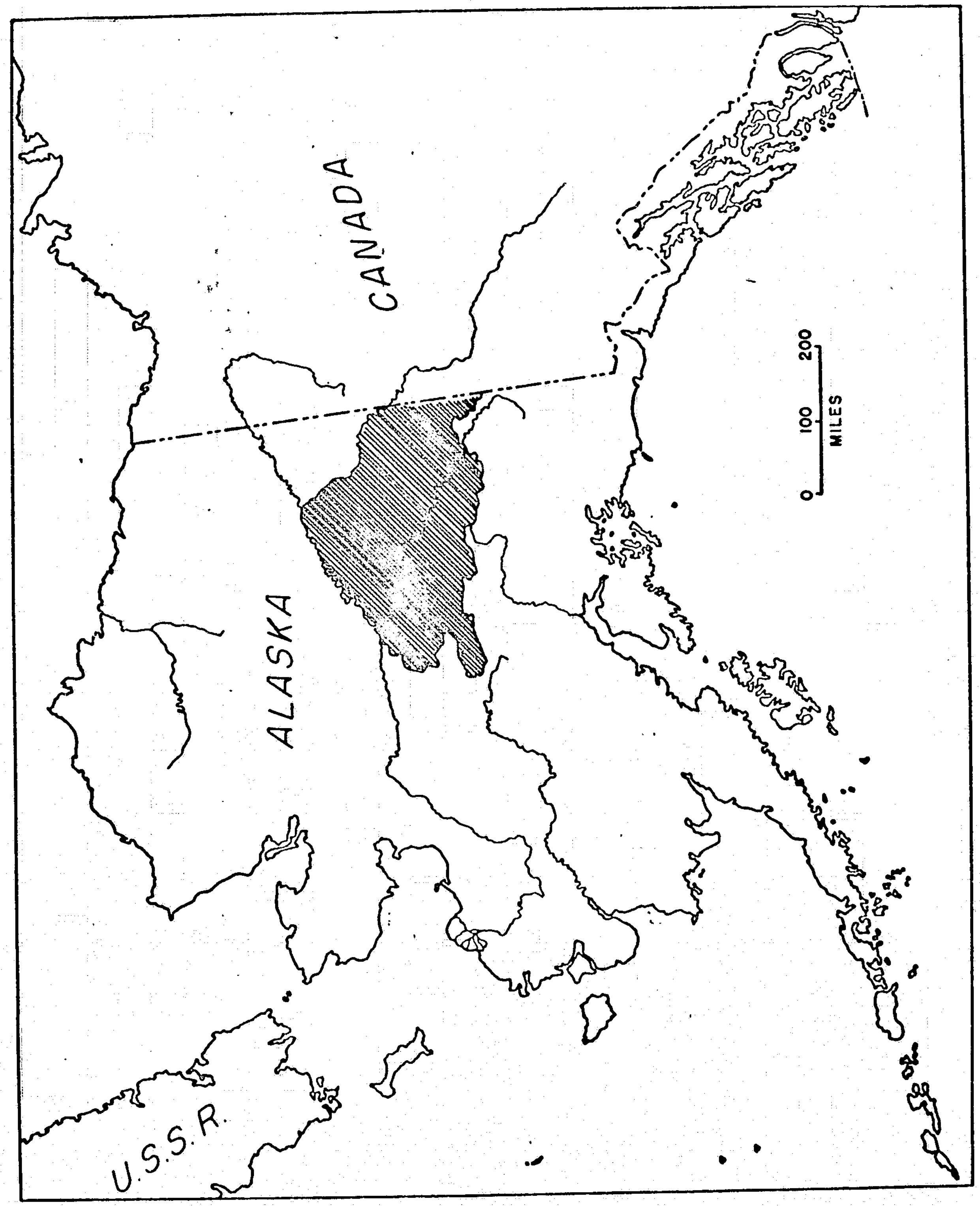
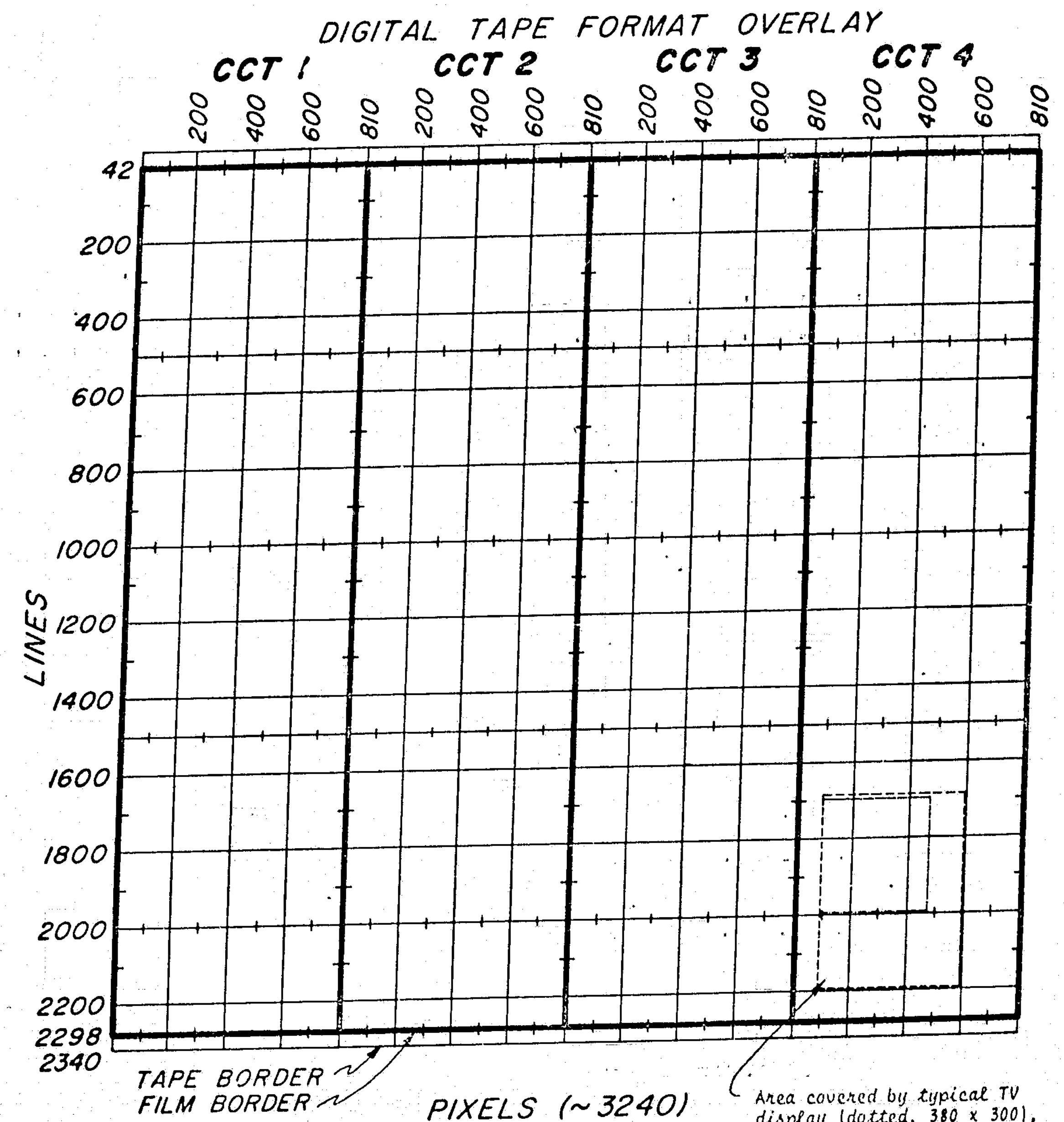

CANADA
ALASKA
U.S.S.R.
0 100 200
MILES

Fig. 2. Print of overlay used for matrix location of LANDSAT CCT data



OVERLAY HEAVY BORDER ON 240MM ERTS SCENE. GRID SPECIFIES THE TAPE, LINE, AND PIXEL NUMBERS FOR A CDU TAPE OF DESIRED AREA. A STANDARD CDU TAPE CAN ENCOMPASS AN AREA 512 PIXELS BY 512 LINES, BUT OVERLAPPING COVERAGE FROM ADJACENT CCT'S IS NOT POSSIBLE.

Fig. 3. Example of line printer maps used by field crews

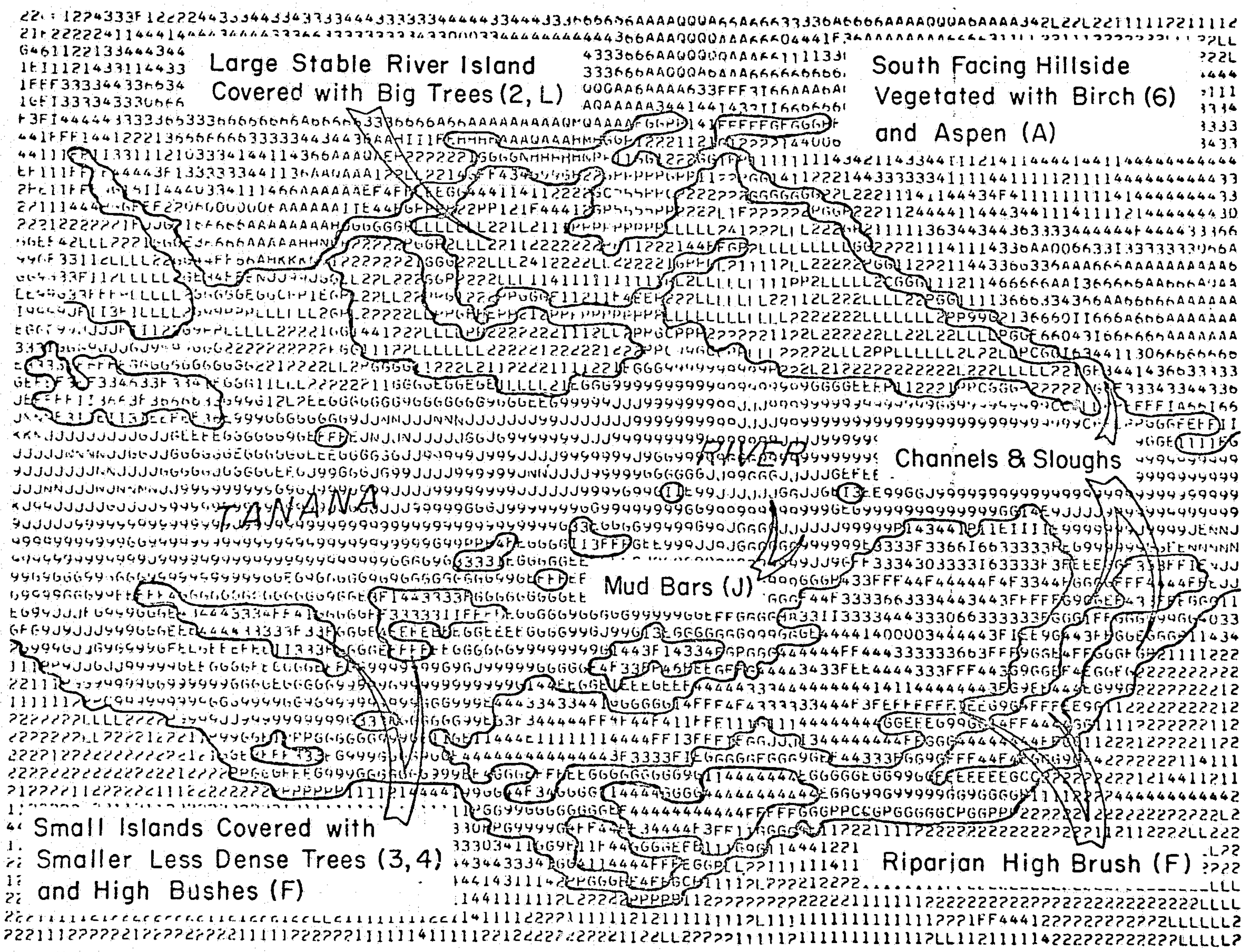
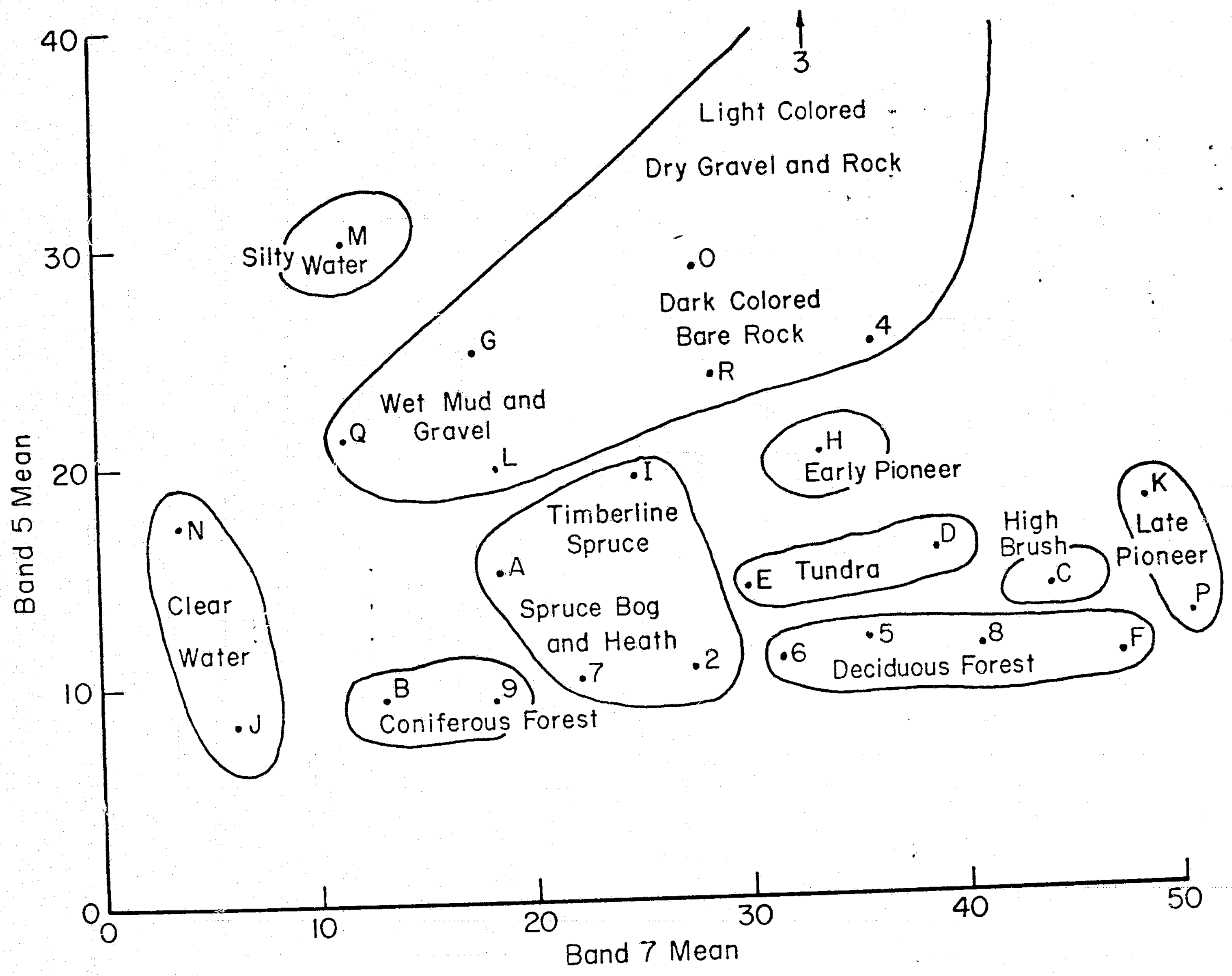

Large Stable River Island
Covered with Big Trees (2, L)
South Facing Hillside
Vegetated with Birch (6)
and Aspen (A)
TANANA
RIVER
Channels & Sloughs
Mud Bars (J)
Small Islands Covered with
Smaller Less Dense Trees (3, 4)
and High Bushes (F)
Riparian High Brush (F)

Fig. 4. Two band graphic presentation of cluster results for scene 1407-20374


Band 5 Mean
Band 7 Mean
0
10
20
30
40
50
3
Light Colored
Dry Gravel and Rock
Dark Colored
Bare Rock
Wet Mud and
Gravel
Silty Water
Clear
Water
Timberline
Spruce
Spruce Bog
and Heath
Coniferous Forest
Early Pioneer
Tundra
High
Brush
Late
Pioneer
Deciduous Forest
M
O
G
R
4
Q
L
I
H
K
N
A
D
C
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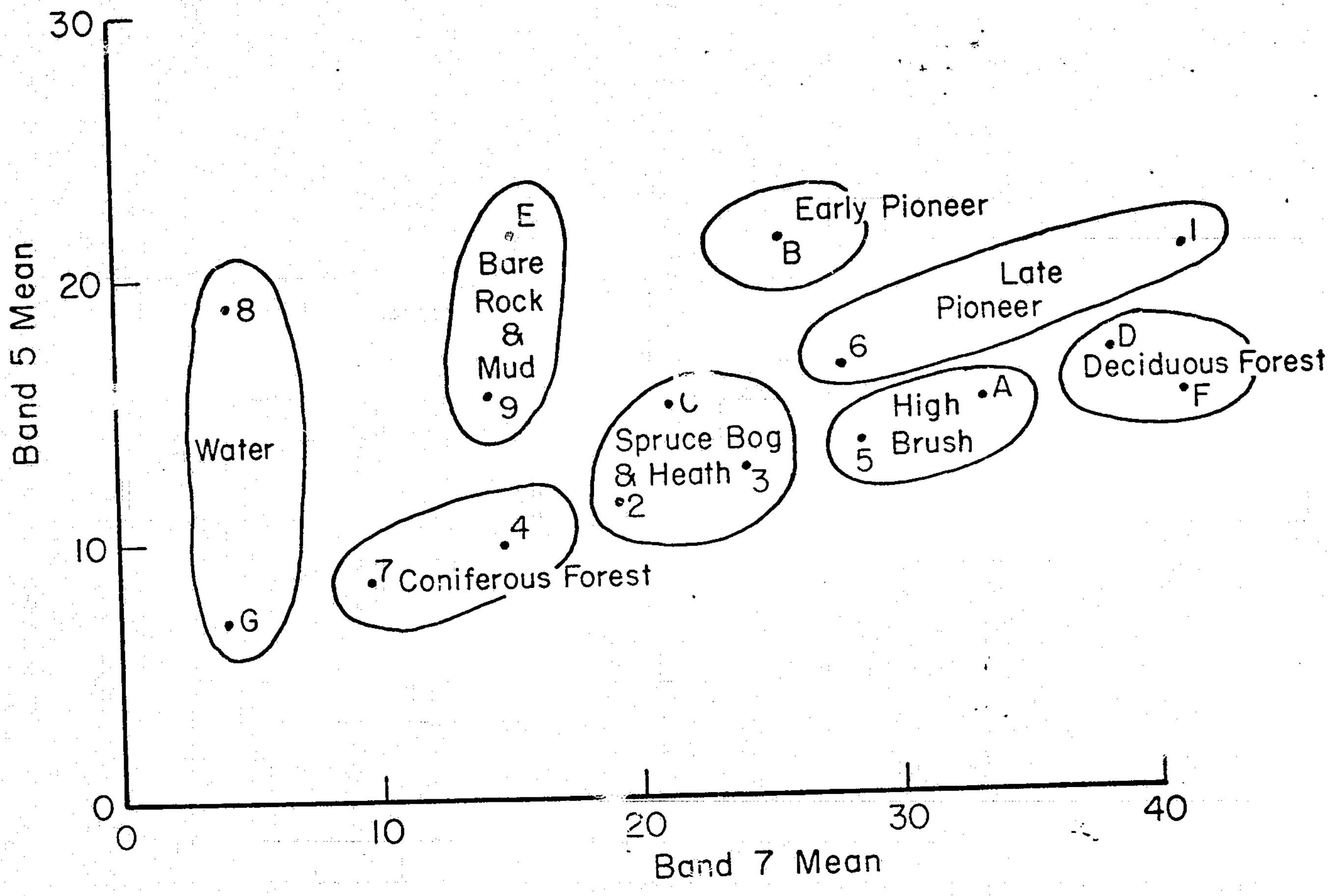
P
5
8
F
6
2
7
B
9
J

Fig. 5. Two band graphic presentation of cluster results for scene 1407-20374


30
20
10
0
Band 5 Mean
0
10
20
30
40
Band 7 Mean
Water
8
G
E
Bare Rock & Mud
9
Early Pioneer
B
Late Pioneer
I
6
Deciduous Forest
D
F
High Brush
A
5
Spruce Bog & Heath
C
3
2
Coniferous Forest
4
7

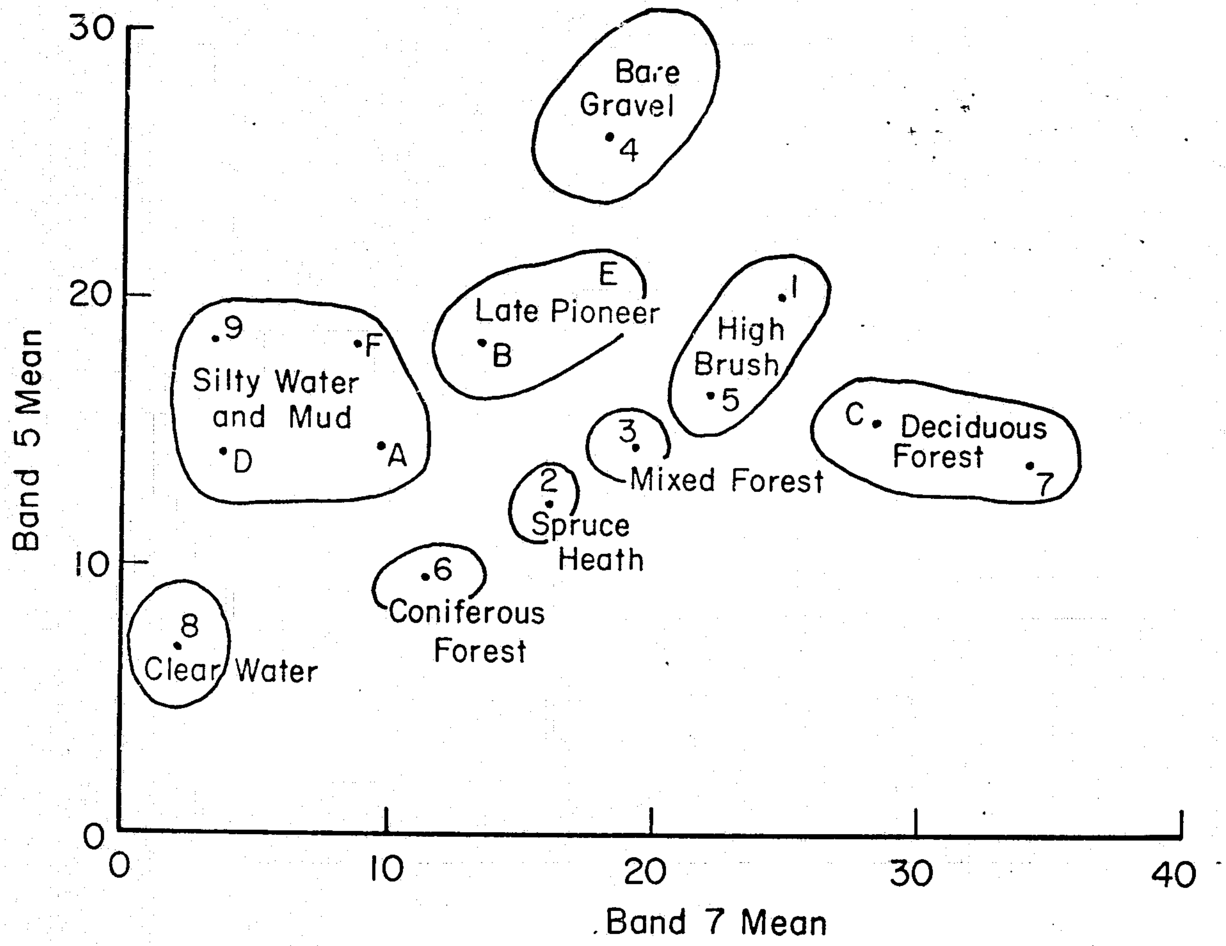

Bare Gravel
4
E
Late Pioneer
B
I
High Brush
5
9
F
Silty Water and Mud
D
A
3
Mixed Forest
C
Deciduous Forest
7
2
Spruce Heath
6
Coniferous Forest
8
Clear Water
Band 5 Mean
30
20
10
0
0
10
20
30
40
Band 7 Mean

Fig. 7. Two band graphic presentation of cluster results for scene 1408-20435

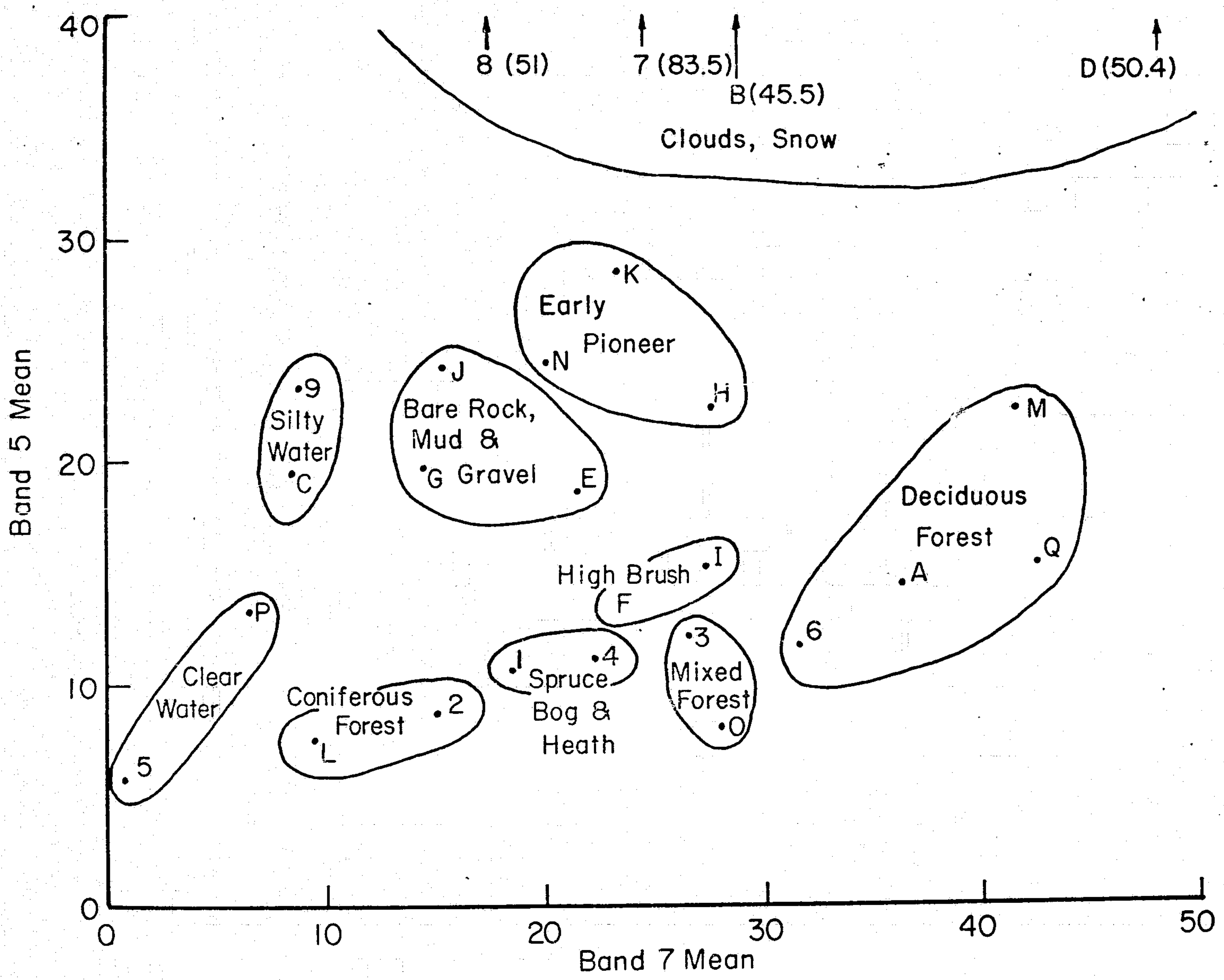

8 (51)
7 (83.5)
B(45.5)
D(50.4)
Clouds, Snow
Early Pioneer
K
N
H
Bare Rock, Mud & Gravel
J
G
E
Silty Water
9
C
Deciduous Forest
M
Q
A
6
High Brush
I
F
Clear Water
P
5
Coniferous Forest
2
L
Spruce Bog & Heath
1
4
Mixed Forest
3
O
Band 5 Mean
Band 7 Mean
0
10
20
30
40
50

Fig. 8. Two band graphic presentation of cluster results for scene 1422-20203

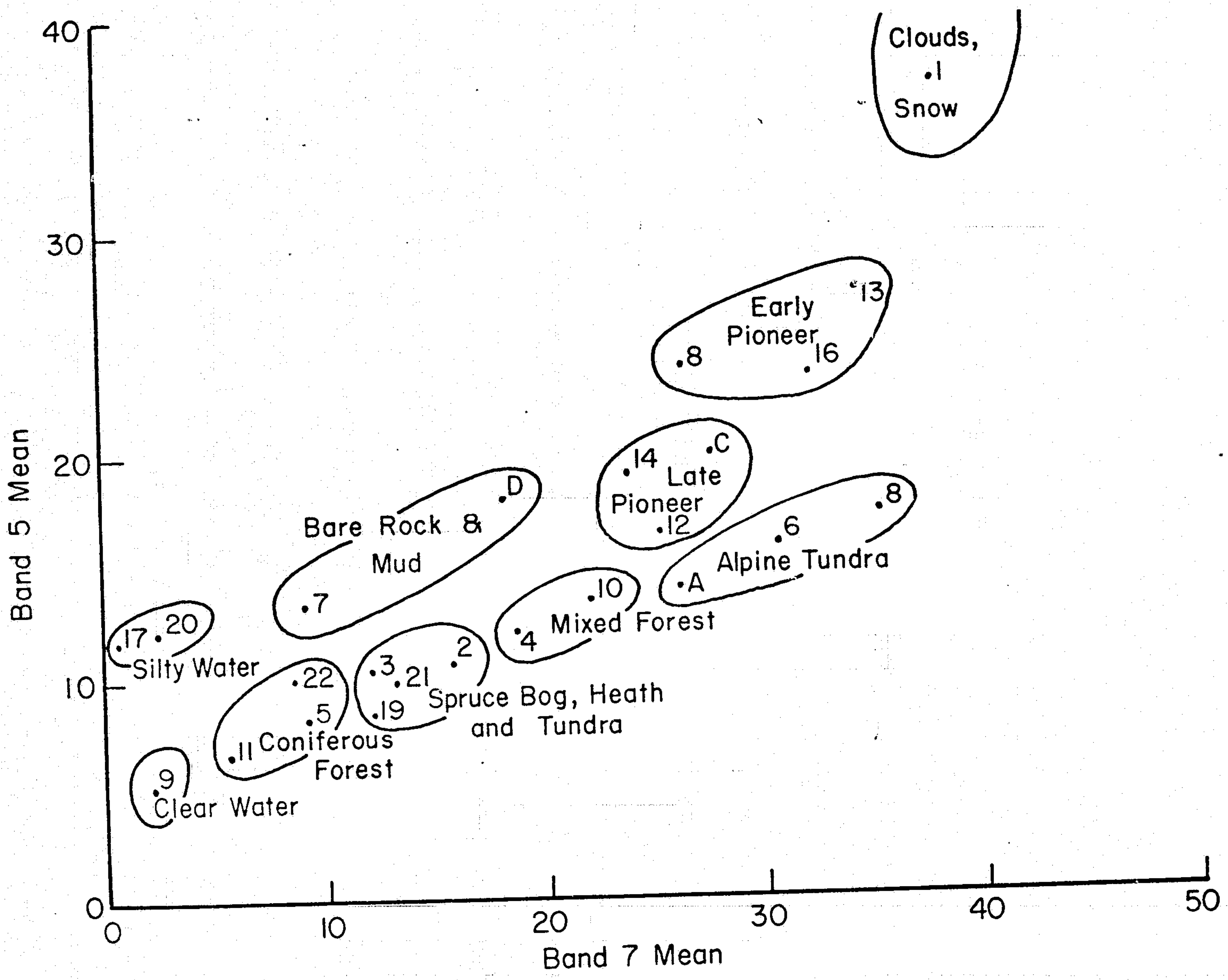
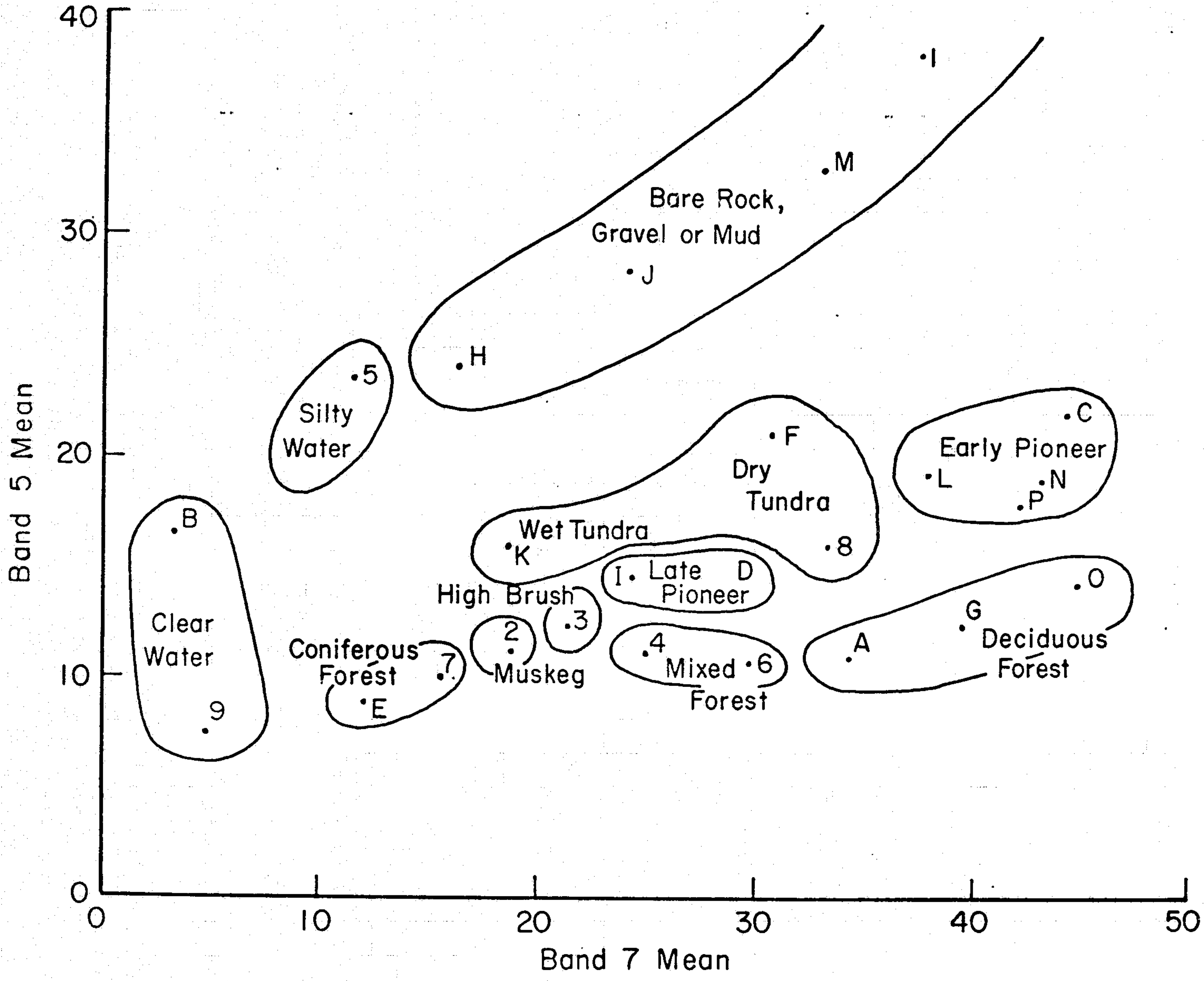

Band 5 Mean
Band 7 Mean
0
10
20
30
40
50
Clouds, Snow
1
Early Pioneer
13
8
16
Late Pioneer
14
C
12
Alpine Tundra
8
6
A
Bare Rock & Mud
D
7
Mixed Forest
10
4
Silty Water
17
20
Spruce Bog, Heath and Tundra
3
21
2
19
Coniferous Forest
22
5
11
Clear Water
9

Fig. 9. Two band graphic presentation of cluster results for scene 1771-20513



Band 5 Mean
Band 7 Mean
0
10
20
30
40
50
Bare Rock, Gravel or Mud
I
M
J
H
5
Silty Water
C
Early Pioneer
L
N
P
F
Dry Tundra
8
Wet Tundra
K
I
Late Pioneer
D
High Brush
3
2
Muskeg
B
Clear Water
9
Coniferous Forest
7
E
4
Mixed Forest
6
O
G
A
Deciduous Forest

Fig. 10. Two band graphic presentation of cluster results for scene 1771-20515

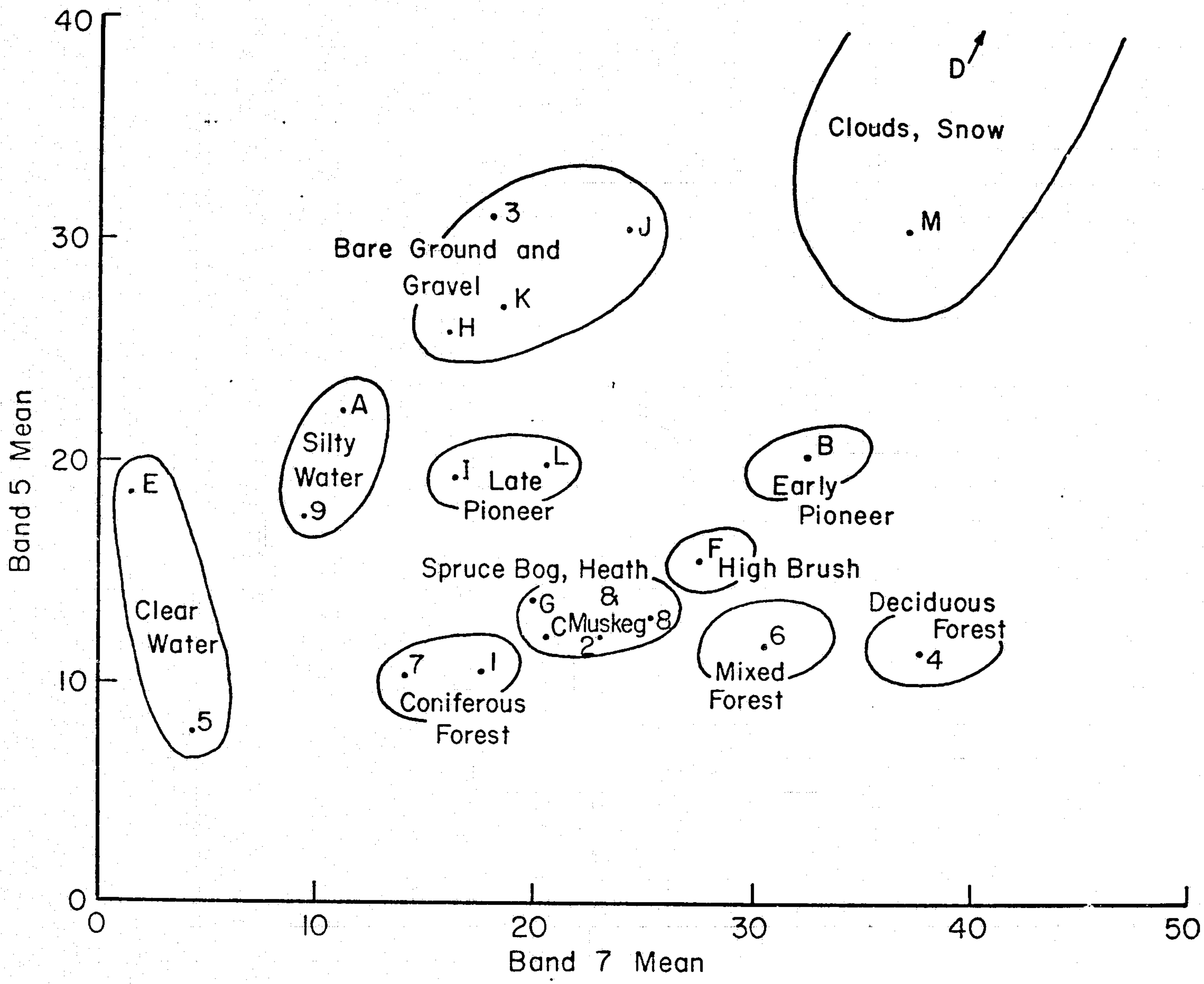
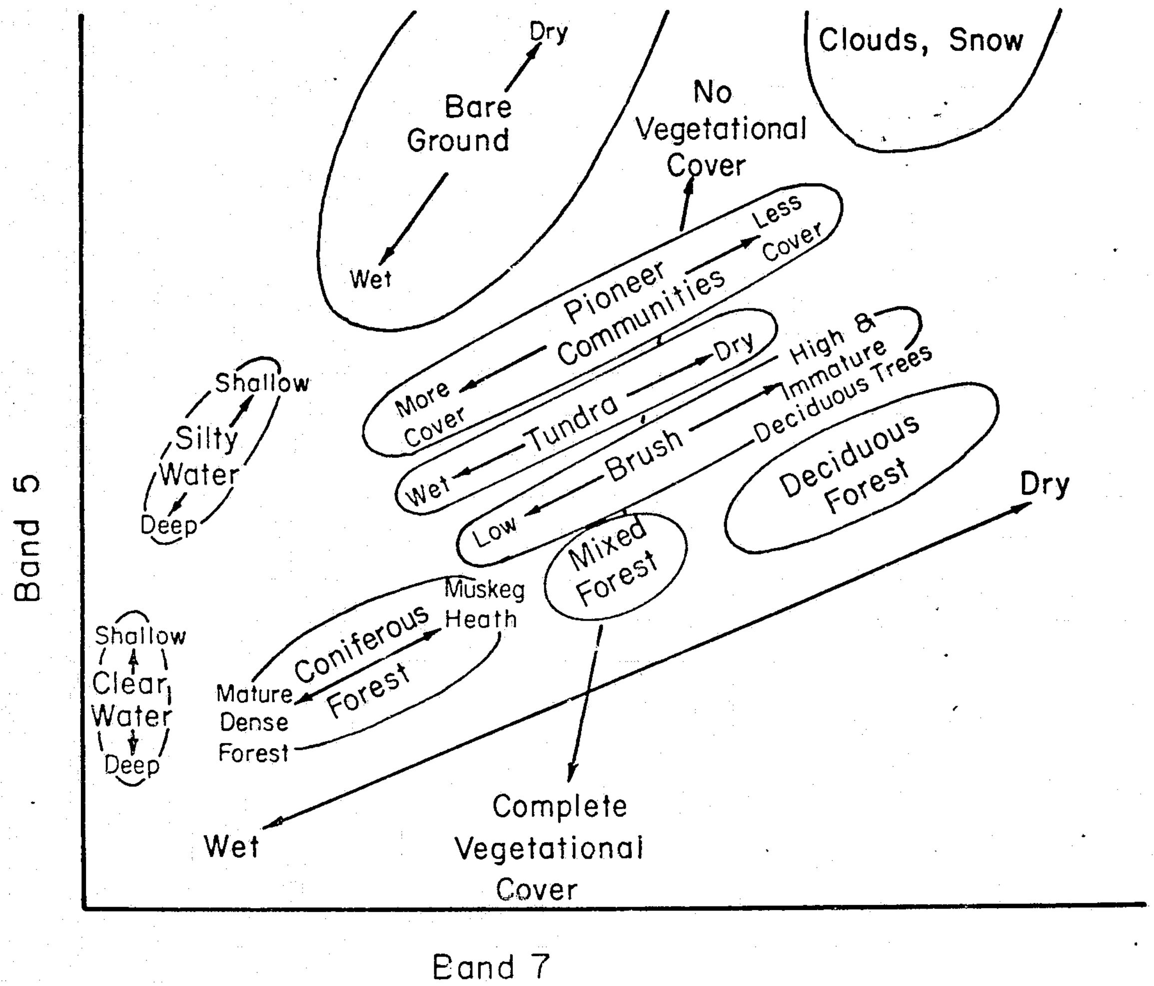

Band 5 Mean
Band 7 Mean
0
10
20
30
40
50
Clouds, Snow
D
M
Bare Ground and Gravel
3
J
K
H
Silty Water
A
9
Late Pioneer
I
L
Early Pioneer
B
Clear Water
E
5
High Brush
F
Spruce Bog, Heath & Muskeg
G
C
2
8
Mixed Forest
6
Deciduous Forest
4
Coniferous Forest
7
I

Fig. 11. Hypothetical example of relative positions and gradients associated with cluster means in bands 5 and 7


Clouds, Snow
Dry
Bare Ground
Wet
No Vegetational Cover
Less Cover
Pioneer Communities
More Cover
Dry
Tundra
Wet
High & Immature Deciduous Trees
Brush
Low
Deciduous Forest
Dry
Shallow
Silty Water
Deep
Mixed Forest
Muskeg Heath
Coniferous Forest
Mature Dense Forest
Shallow
Clear Water
Deep
Wet
Complete Vegetational Cover
Band 5
Band 7